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PI: Roger M. Samelson

Title: Predictability in Unstable, Continuous Systems/Predictability and Dynamics of Geophysical Fluid Flows

Research under this grant focused primarily on computations of unstable nonlinear periodic solutions, time-dependent normal modes (Floquet vectors), and singular vectors in a two-layer quasi-geostrophic channel model. The model was studied in weakly and strongly nonlinear regimes, in which small disturbances to an unstable, steady, zonal, baroclinic shear flow grow to finite amplitude and continue to vacillate irregularly for arbitrarily long times. The computation of time-dependent, normal-mode disturbances to unstable, nonlinear, time-periodic basic flows in a high-dimensional geophysical fluid model opens a new perspective on the analysis of disturbance growth in time-dependent flows, and on the closely related problem of error growth in predictive models of time-dependent flows.

In the strongly nonlinear regime, unstable periodic solutions were identified and computed using an efficient Newton-Picard method. The complete Floquet spectra computed for strongly nonlinear cycles show structure similar to that found in the weakly nonlinear case. The Floquet vectors fall into two classes with direct physical interpretations: wave dynamical (WD) modes and damped-advective (DA) modes. The WD modes have large scales and can efficiently exchange energy and vorticity with the basic flow; thus, the dynamics of the WD modes reflects the dynamics of the wave-mean oscillation. These modes are analogous to the normal modes of steady parallel flow, and the leading WD Floquet exponents provide useful approximations to the leading Lyapunov exponents of the chaotic solution to which nonlinear disturbances to the unstable periodic cycle converge. The DA modes have fine scales and dynamics which reduces, to first order, to damped advection of the potential vorticity by the basic flow. While individual WD modes have immediate physical interpretations as discrete normal modes, the DA class instead represents a generalized solution to the damped advection problem. The existence of these two classes of normal-mode solutions to the numerical Floquet eigenvalue problem indicates a dynamical splitting of the linear disturbance problem for this time- and space-dependent baroclinic flow.

AWARDS

Christopher L. Wolfe, Student Fellowship, Woods Hole Summer Program in Geophysical Fluid Dynamics

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